Grant #N00014-93-1-1044

NEAR CANOPY ARCTIC ACOUSTIC BACKSCATTERING STUDY
Final Report May '93 - Sep '94

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ABSTRACT

We collected under-ice backscattering data with a low-frequency (400 Hz), spatially-diverse, transmitting and receiving array during the ONR SIMI project in Spring '94. The experiment, termed IBEX (Ice Backscattering Experiment) was based on the idea that such arrays of sources and receivers can be used to make images of backscattered sound when the geometry is very well known. The data has been processed using interferometric (time delay) imaging to localize high scattering regions. The measurements were made in two locations; one directed at imaging a large ridge, the other directed at imaging an $\approx$ 1000 m diameter expanse of a single floe. The measurements were carried out using several pulse types. We also operated a hyperbolic noise event tracking system to locate ice-cracking events and initiate an imaging sequence. The noise levels and activity were so low during the experiment period, that this feature could not be utilized. The ridge imaging was a collaborative effort with the MIT Group under the direction of Hendrik Schmidt. We have not received the MIT data for the combined effort - at this writing.

INTRODUCTION

The CAscadia Basin EXperiment (CABEX) was conducted in February/March 1993. An array of transmitters and receivers was used to image the backscattered sound from the sea surface zone. The equipment was developed at APL by the Multi-Discipline Group. On its first deployment it performed reasonably well, and allowed us to test the concept of using distributed sources and receivers to image the surface. The engineering principles upon which it was built and the capability of the resulting hardware was ideally suited for imaging the underside of the Arctic ice field, and the ONR SIMI project gave us an ideal opportunity to make such measurements. The system (Figure 1) was particularly well suited for deployment from the Arctic multi-year ice and imaging of the underside of the ice canopy was accomplished with the array. This imaging, in conjunction with supporting ice characterization, gives insight into those ice characteristics that are

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1. This confirms our conversations of 27 Feb 97 and 11 Jul 97. Enclosed are a number of technical reports which were returned to our agency for lack of clear distribution availability statement. This confirms that all reports are unclassified and are "APPROVED FOR PUBLIC RELEASE" with no restrictions.

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ROBERT J. SILVERMAN

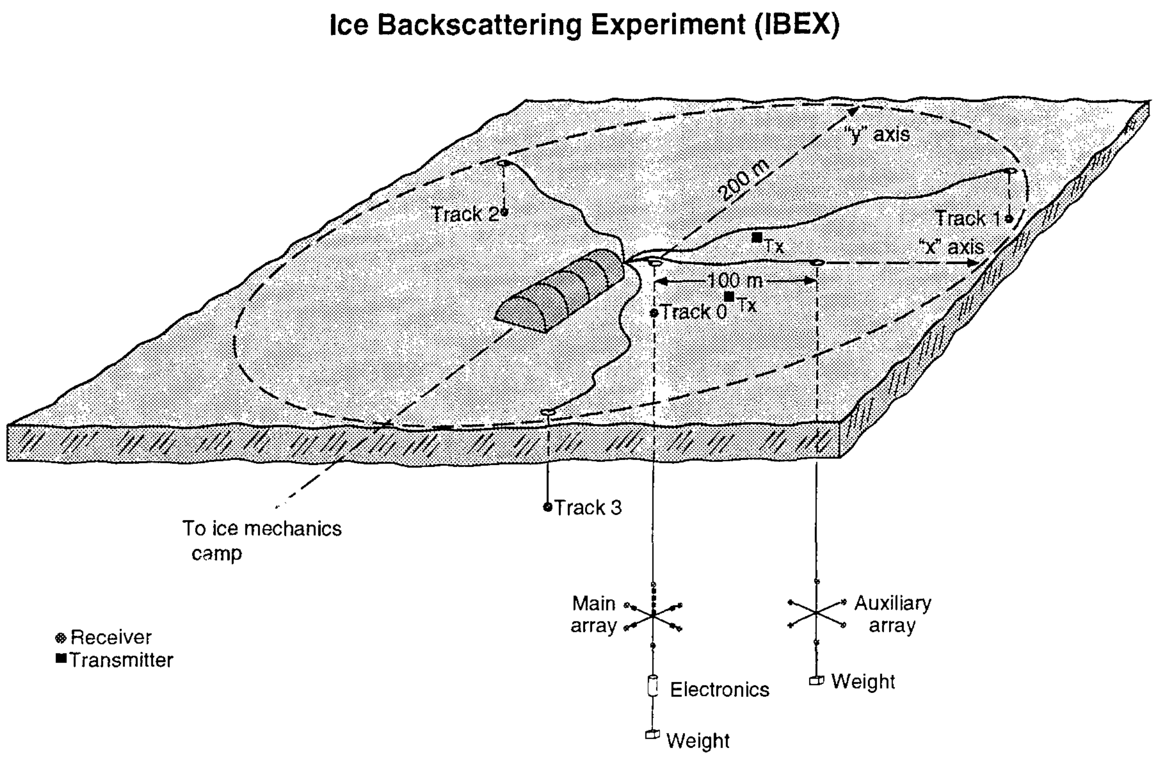
Ice Backscattering Experiment (IBEX)
"y" axis
200 m
Track 2
Track 1
Tx
"x" axis
100 m
Track 0
Tx
Track 3
To ice mechanics camp
Main array
Auxiliary array
Receiver
Transmitter
Electronics
Weight
Weight

Figure 1.

important to include in low frequency scattering models, as well as allowing tests of present scattering models. During the experiment we also took several pictures of the ice floe region to compare the surface expression of the ridging with the backscattered sound field. This could pave the way for developing a low frequency backscattering model from satellite photos.

LONG RANGE OBJECTIVES

Our long range objectives are: (1) to relate the scattered underice sound field to ice characteristics and deterministic processes observed in the ice-mechanics experiment, and (2) to collaborate in the testing and further development of low frequency propagation models. In future efforts, these relationships could allow low frequency experiments to be initially used to target likely areas of high activity that are good candidates for instrumentation.

SPECIFIC OBJECTIVES of IBEX

Our approach was to perform low frequency scattering experiments where an approximately 1 km^2 area of ice canopy was imaged that was also being characterized environmentally during SIMI. This allows deterministic comparison between the acoustic backscattering and physical characteristics of the ice. Collaboration with David Farmer of IOS will allow the ambient noise environment to be correlated with low frequency scattering data acquisition. Collaboration with Hendrik Schmidt of MIT is anticipated to allow testing of current propagation and scattering codes. These objectives will be carried out under the funding from the ONR 5 year award to Dr. Terry Ewart and the Multiple Discipline Group, MDG.

Instrumentation

The CABEX arrays were modified for deployment through the multi-year ice, and for transport in a Twin Otter aircraft to the site. A 2 kHz ice mounted tracking system was developed and deployed to facilitate the precise location of the array elements. The deployment and operation of the equipment went very smoothly. The operation, 2 km remote from the SIMI camp, consisted of two 8'x16' tents. In one were four bunks, three computer workstations, a heater, and water storage. The other tent was used to ready the arrays for deployment. During the operation, that tent was used for eating and performing repairs and maintenance. The major problems were caused by the static inverters used for powering the three workstations and other apparatus at the site. This forced us to run a generator during some of the operation, which increased the noise levels.

Analysis to Date

The ice backscattering data was retrieved to a master workstation via Ethernet from the array electronics. The data consists of the tracking information plus other diagnostics, and the time series from each of the twelve receivers of the two arrays. The separation of the two arrays was 100 m (see Fig. 1). To illustrate the capability of the imaging algorithms, we have included Figures 2-6. These show the effects of spatial diversity and coherent averaging on the clarity of the backscattered image. In Fig. 2 we see the image formed

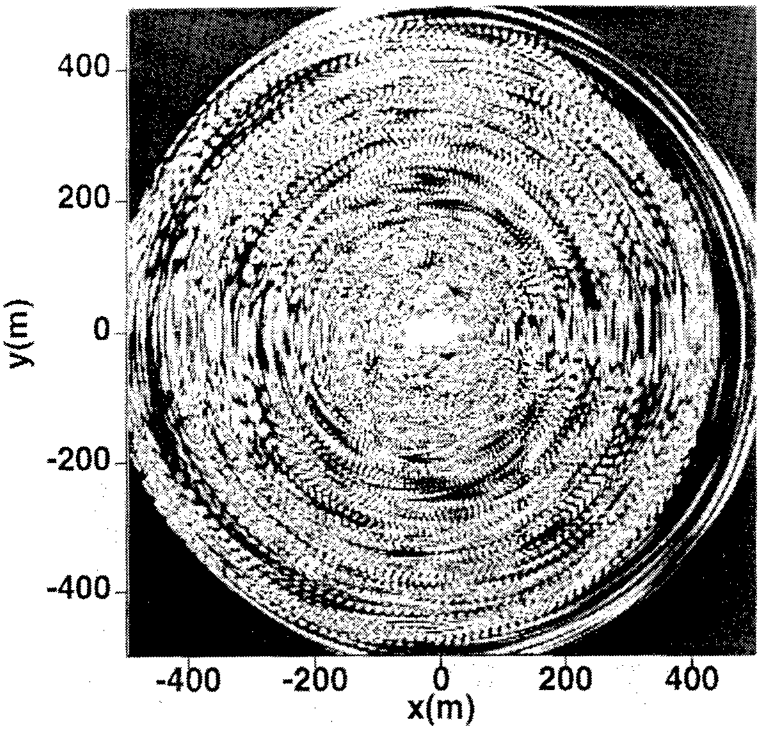

Figure 2.

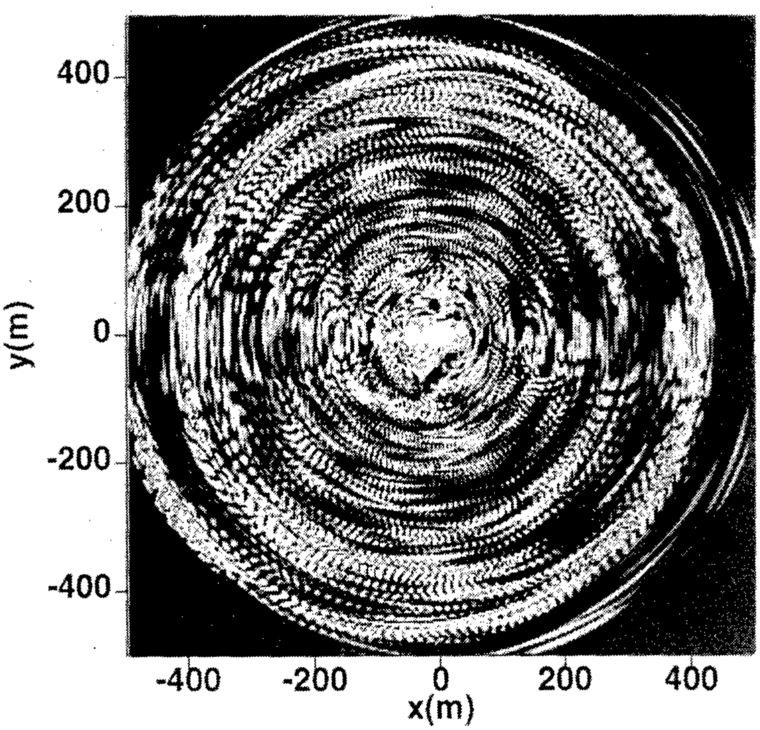

Figure 3.

using all of the receivers and only one transmitter. Fig. 3 shows the same image where 7 transmitters are used. The reduction in sidelobes is very apparent. In Fig. 4 three pulses have been averaged (coherently) to form the image and another reduction in sidelobes is clear. Fig. 5 shows the same three pulse averaging with all transmitters as Fig. 4, but was taken after the Auxillary array was moved to a position 90° from the initial location. Here the symmetry of the arrays has clearly changed, but the sidelobe structure is about the same. In Fig. 6 the six pulses from Fig's 4 and 5 have been coherently processed to effectively add 6 more receivers with significantly increased spatial diversity. The sidelobe structure is much reduced. We had proposed to increase the bandwidth of the sources from 200 Hz to 1 kHz. The effect of this change would have produced a dramatic reduction of the sidelobes near the brightest image locations. Funds were not available to effect those additions.

The photos taken from the helicopter have been processed to the same x-y grid as the acoustic images. During the experiment we had used a laser transit borrowed from the APL Arctic Group to survey in the locations of our apparatus and also the locations of prominent surface features. These features were used to obtain the photo-to-(x-y) transformation, as they can be readily seen in the photos.

We have developed four different imaging methods to locate the highest intensity scatterers and to image the scattered field. The best performance to date with simulated data has been achieved with a detection algorithm developed by Frank Henyey and Terry Ewart that utilizes the localized source properties of the backscattered field. A minimum variance technique, a third moment technique, and a standard Bartlett technique (used in Fig's 2-6 above) have been implemented. When the MIT data is available, these algorithms will have to be modified to incorporate their data in the imagers. This will be especially important for the ridge scattering measurements. The ultimate goal of measuring the ridge response is to allow development of a more comprehensive backscattering model based on the statistics (from satellite photos) of the ridging.

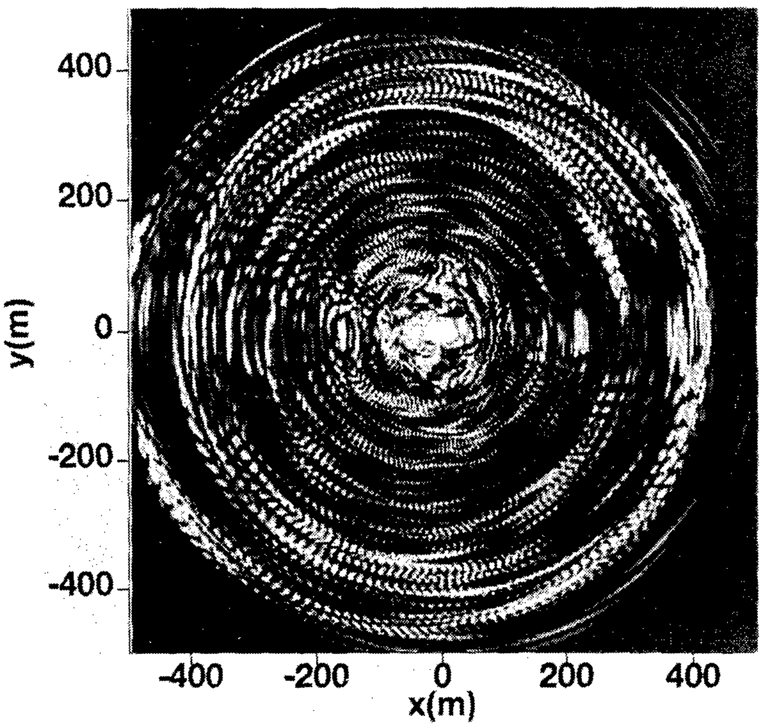

Figure 4.

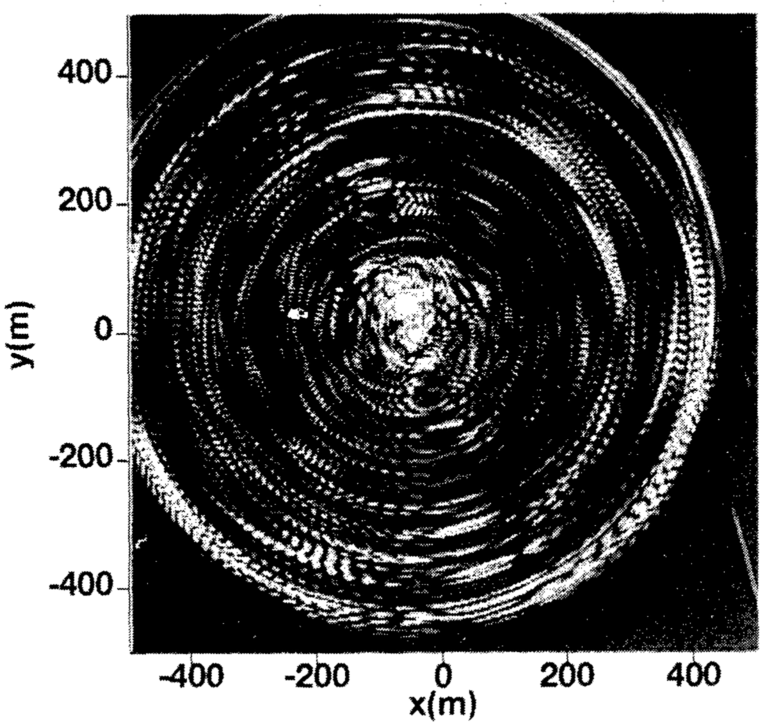

Figure 5.

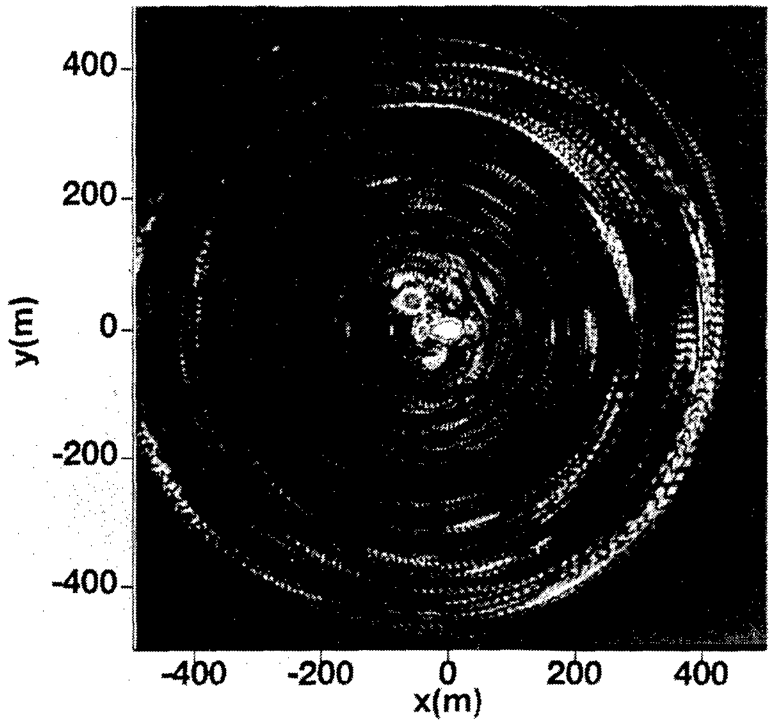

Figure 6.